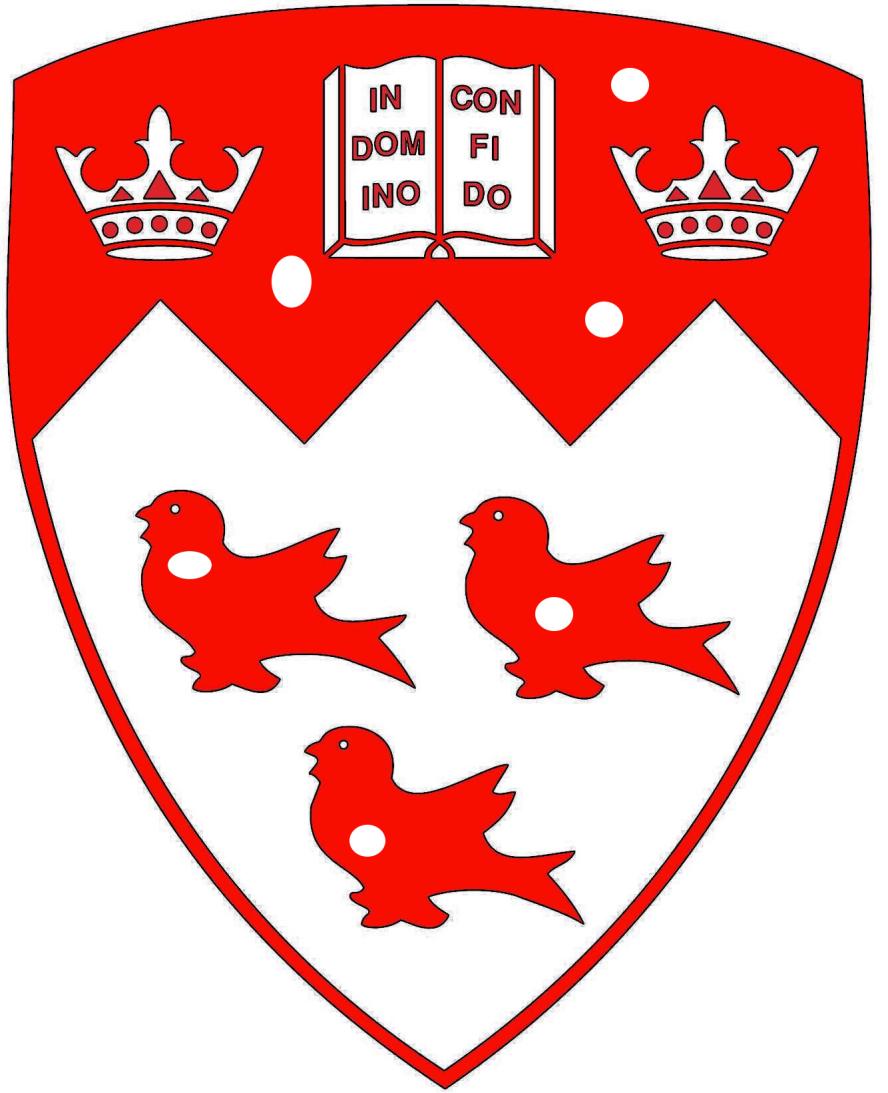
**Team 10 Final Report**

**ECSE 211: Design Principles and Methods**

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# 1. Introduction

The goal of this course is to understand some of the basic principles and methods behind the iterative process of engineering design. The process of design is fundamental to all branches of engineering, a systematic procedure that begins with the formulation of a precise specification of the problem at hand and ends with the specification of a procedure and/or mechanism that meets the requirements outlined in the problem specification. The design process itself consists of identifying the constraints that surround the problem and manipulating the design variables such that a solution that meets the constraints in an optimal fashion is found.

The goal of this project was to construct an autonomous robot that could successfully complete a game of Capture the Flag. The primary complication for the project is that the two obstacles for crossing between regions have different widths. In order to smoothly traverse the bridge, the wheelbase must be wide enough so that the wheels fit into the tracks and it has bumps, however this same wheelbase is too wide to fit through the tunnel. Hence the challenge here is to find a vehicle configuration that can navigate both the bridge and the tunnel.

# 2. Team Organization

**How were tasks allocated?**

The team consisted of six members from electrical, computer, and software engineering. At the start of the project the group met up and discussed the skills and strengths of each member. Members rated themselves on a scale from 1 to 5 for different skills, including management, hardware, software, and writing. From this, each member was assigned a role. Tasks were primarily allocated based on these roles, in addition to each team member’s availabilities throughout the project duration.

**How was the initial Gantt chart designed?**

The timeline set for each task in the Gantt chart was based on the initial general lab tests performed earlier in the course. Resources were assigned using information gathered on each team member’s skills in each area of expertise, as well as availability throughout the semester. In general, tasks on the crucial path were given priority over non-essential tasks in terms of budget and resource allocation.

**What information was used to estimate the initial task breakdown?**

Our methodology consisted of breaking up the entire build into smaller and more manageable subtasks. We then identified the most crucial tasks and evaluated the interdependencies between them in order to minimize these dependencies . Our goal was to standardize each component to make them relatively independent from the rest of the build. This process was meant to minimize conflicts when assembling the final version of the robot and prevent constant exchange of version information.

**Were any guidelines followed in developing the first version of the chart?**

For the first version of the chart, we concentrated on testing on each component. So we covered all the areas through testing, so that we can come up with design models that will suit to our requirements and plans. We loosely followed an agile development strategy while developing the Gantt chart in order to continually improve our hardware and software designs.

# 3. Issues encountered in the progress of the project

**Were all the dependencies correctly identified at the start of the project?**

All initial dependencies were correctly identified and managed into subtasks by means of a Gantt Chart. The chart was divided into major parts including mechanical design, software architecture, testing and documentation. Each of the sections mentioned were dependent on one another. For example, without physical dimensions, it would be very difficult to implement localization and odometry. Also the bridge and tunnel wheelbase factor played a crucial role in case of difficulty in order to design a functioning hardware. The dimensions of the part of the robot play fundamental roles in localization and odometry.

**What dependencies contributed to the critical path of the project?**

The critical path is given by the following dependencies: Mechanical design idea, software proposal, software architecture, mechanical final design, code mash up, first part of testing, beta demo, integration of testing for competition and final competition. This is the basic structure of the entire project.

**What initial ideas turned out either not to work or be based on wrong assumptions?**

Many ideas are abandoned for different reasons. For example, the foldable-wheel mechanical model (Model 2.03) was abandoned because it was unrealistic to build given the constraints on the size of the robot, and because only certain sized motors are provided. Moreover, the varying wheelbase model (Model 2.01) was abandoned. It is because the wheelbase is not consistent as it will change when it crosses the bridge and it will create errors on navigation.Additionally, we originally intended to use the dual light-sensor setup for odometry-correction throughout navigation. This proved to be too difficult to implement, so we instead decided to use the sensors for line detection at certain points during navigation.

**What other issues/factors had an impact on the project? How did these affect the project progress?**

Time is the most important factor for this lab. Our search method didn’t perform very well in the competition. We believe that given more time, we could improve the search method to perform more reliably. Communication was also very crucial throughout the project. The whole design process involves a lot of feedback. The software engineers and hardware engineers give their requirements to each other, then the prototypes sent to testers. Testers collected data and gave suggestions about what needed to be changed. This process was iterated many times before we finally got successful results. Communication could have improved within the team with regards to documentation.

**In particular, did the project run to the plan you had initially created?**

The team was divided with the task which is within each personnels capability. At the beginning of the project we concentrated more on design and testing keeping the robot software simple. However as the project ran, lots of complications were faced and later we were behind schedule. Thus at the end of the project team members pulled off extra hours to find the solutions to the problems. Hence it did divert the team from the initial plan of following the design process, but overall the team was satisfied with the outcome.

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# 4. The Budget

**What constraints did the budget place on your team?**

Each team was provided with a total of 9 hours per team member per week, totalling 351 hours for the team. This budget forced the team to focus on simple solutions that could fit within the budget, rather than always picking the best solution. For example, we were forced to abandon full odometry correction, instead focusing our time on discrete odometry correction using line detection.

**How did initial planning for available resources and budget spending affect the development of the timeline?**

The initial planning of resources helped to guide our understanding of how much time was required for each phase of development. We stayed mostly on track with the schedule throughout the project.

**Did you allocate resources to all the project tasks, i.e. all the way to 15 April, at the start of the project and use this to estimate the budget. If not, explain why not.**

We did allocate resources for all project tasks after the first week into the project. Throughout the project, the resources were updated to account for discrepancies between the planned and actual hours spent.

**What would you have spent if there had been no limits on the budget and when in the process would extra budget have been useful?**

An unlimited budget would have provided enough freedom and time to implement better code, including automated testing, since more time for debugging and testing all critical components of our final design would have been available. Additionally, we would have improved upon odometry correction, flag searching, and obstacle avoidance algorithms.

**Where were you weak in resources and what would you have done to resolve this issue if you had fewer budgetary constraints? At what point in the project could these extra resources have been brought in?**

Considering the constraints and budget, the only lacking resource was time. All resources regarding hardware and software came well-provided by the designated Lego kits and leJOS EV3. Only the time factor became a huge problem to come up with a stable solution. On the other hand, the team was mainly based on Electrical Engineering students. Only two personnel worked on Software, thus most of the improvements were hardware based. We could have used extra time budget on our subtasks and testing for each component for perfection.

# 5. How the process contributed to the success (or failure) of the project

**Was the process useful in achieving the goals?**

Yes, process was useful in achieving the goals. Every week, each team member was assigned and responsible with different tasks. The tasks were done independently and simultaneously in an organized manner by each member. As a result, the robot was able to achieve all of its goals.

**How would you modify the process to increase your probability of success?**

It would have helped to increase the frequency of face-to-face interactions between team members. Instead of having members work primarily individually, weekly group meetings would have been more effective in terms of exchanging ideas, solving problems and gaining a better understanding of what others were doing and how much progress had been made.

**Which parts of the process were the most difficult to implement and why?**

Since team members were working individually, it was sometimes difficult to combine all the tasks together and make the robot achieve its goals. Different team members sometimes did not have the same interpretation and expectation of the tasks which could result in deviation of design which required changes afterwards. Moreover, some tasks were heavily dependent on the other tasks. For instance, obstacle crossing relied upon extremely precise navigation and correction. Since these tasks took longer than expected, we ended up delaying some other tasks.

**How much time was devoted to testing?**

Around 30% of our budget was devoted to testing. Unit testing was carried out in the first half, while integration testing was more heavily weighted toward the second half of the project since it required hardware and software integration. Testing was carried out continually as we updated the software.

**Was this at the subcomponent level or did you leave it all to the end?**

Testings was separated into different phases. Unit and integration tests were carried out throughout the project at the subcomponent level as our first phase, but generally not documented since they were using incomplete implementations of hardware and software. Most documented integration testing was completed after the beta demo in our second phase, once the initial software was complete.

**Were the tests you designed sufficient?**

Yes. We tested all parts of the competition as well as the integration test. There are 6 main tests we implemented: hardware test, Localization test, Navigation test, Search method test, Bridge and tunnel passing test and integration test. They are done in parallel with software. Each test gave important feedback to a particular component of the robot and helped us to optimize and improve our design both on software and hardware as the project moved on.

**How much time did you estimate full prototype (i.e. integration) testing would take?**

We expected the integration testing to run from March 28th to April 10th, which is 14 days in total.

**How much time did it actually take? If there was a difference, why?**

It actually took 12 days because there was a problem in hardware design so the progress was behind the schedule. At first the bridge test results showed that the possibility for the robot to pass the bridge was lower than our expectation. Because of this, we changed the hardware design and redid the test.

**How would you change your test design process to make it more effective?**

Tests and their layout could have been planned out better ahead of time with the software team to avoid time conflicts such as waiting for testing to be completed in order to move on to other phases.

**What was the impact of the beta demo on your design process?**

The beta demo was essential as it was a milestone. It allowed us to clearly identify what stage we needed to be at. From that point, we were able to reevaluate our progress and reallocate the remaining resources for particular tasks such as testing, hardware and software improvements to ensure that the project was finished on time.

# 6. The success of the Design (Robot) in meeting the original specifications and the performance requirements

**What is your impression of how the robot performed?**

When the robot was run on the larger floor, it did require a few changes in hardware and software, but in the end it performed quite well as we expected. On the competition day, out of the four rounds, our robot had one perfect run excluding search, and one run that succeeded in searching but failed to return to the starting corner.

**Did the robot perform as you expected – i.e. if you wrote down what you thought it would do before the demonstration, did it meet or exceed these expectations?**

The night before the competition, our robot was able to perform 3 perfect runs in a row before we stopped testing. During the competition, the robot encountered some issues, including a problem sending updated code to the robot in advance. This resulted in the robot performing slightly worse than expected, however it did manage to accomplish all of the primary tasks over the 4 runs.

**If the robot failed (i.e. did not meet all the performance requirements), why did it fail? Can you point to the sections of the documents that describe the decisions that led to the failure (provide the references to those decisions)?**

Although our robot failed during some individual runs, it was able to perform all tasks at least once during the course of the 4 runs. A decision to skip the search was made in order to maximize our chances at scoring points for most the tasks. The reasoning behind this decision can be seen from the results of the Beta Demo Testing 12x12 and the Full Integration Test 12x12. The success rate during the tests when ignoring the search was much higher than when attempting to complete all objectives. We were able to perform our search algorithm on a later run.

# 7. Conclusions

**What did you learn from this course?**

From an engineering student perspective, we’ve become familiar with the different aspects of the design process and how the real world works. Most importantly the course taught us team building and time management to tackle a problem and to come up with a design solution with limited amount of resources. Thus with the completion of the course, the team feels more confident with the career choice, as it gave the members a glimpse of the real world and its challenges in the field of Engineering.

**Explain why a clear, effective and controlled process is necessary when working in a team and what it helped you achieve.**

One of the major factors in delivering a successful project is applying the required level of project controls. Several inputs define how much control is necessary. Ultimately, these also define the size of a project controls team and the best systems to execute the project.

**Is any of it applicable to other courses you might take? If so, what and why? (name the courses)**

This course may be well be the backbone for other higher level design courses such as the design project - ECSE 456 and ECSE 457. This course is the stepping stone to many other higher level courses including COMP 306, ECSE 424, ECSE 439, given its basis in design fundamentals.

**What would you change in what you did if you were doing it over?**

If the team had to do it all over again, we would have focused more of the team’s efforts on software, including algorithms for search and odometry correction. This would have improved the consistency of the robot and additionally helped by allowing us to perform full integration tests earlier on, something that we had difficulty with given its delayed critical path. Distributing the budget more evenly could have helped with boosting the team’s morale through more frequent, incremental improvements.

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# Declaration

The undersigned members of team 10 agree that the contents of both this report and the information handed in on cd, dvd or memory key, provide an accurate representation of the work done on this course and the contributions of each team member.

**Max Musing (Team Manager) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

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